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HAIL DAMAGE TO CORN

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CONTENTS AND SUMMARY

[1]The front cover shows the extent to which it was possible to imitate actual hail damage through artificial methods. Also see figs. 2, 3 and 4.

Hail Damage to Corn[1]

By JOHN C. ELDREDGE[2]

Each year thousands of Corn Belt farmers, as they nurse their crops from kernel to ear, watch gathering rain clouds with a hopeful eye. And each year, instead of the gentle shower of their anticipation, many of these farmers see the dreaded hailstorm come pounding across the country-side, leaving in its wake a path of twisted, bruised and broken corn plants.

Depending upon the stage of development and the apparent severity of the damage, there follows the indecision as to whether to replant, replace with another crop or hope that following conditions will be favorable to the damaged field. Or, if the farmer is one of the large percentage of middlewestern farmers who carry hail insurance, there follows the problem of a satisfactory adjustment.

Some idea of the importance of this problem to Iowa farmers is found in the fact that annual hail damage in this state alone often runs to more than 4.5 million dollars, with more than one-third of the state annually reporting some damage from this source. It has been estimated that farmers in Iowa have one chance in six of having crops damaged by hail.

PURPOSE

Probably one of the most important factors contributing to the difficulty of making loss adjustments on hail damaged crops is the lack of information on the physiology of the corn plant. Many adjusters in the past have claimed that leaf damage was unimportant, while others have allowed total damage on bruised stalks where the yield was probably not reduced by as much as 20 percent. Farmers have insisted, also, that following a hailstorm a field of corn or small grain would suffer an epidemic of smut or other disease, or that if 10 percent of the tassels were damaged the pollination would be poor and the yield consequently reduced. Each group has been both right and wrong at times.

All of which indicates the need of investigating hail injury to crops. On the one hand there are crop losses, due to hail, of millions of dollars annually and a hail insurance business greater than all other forms of farm mutual insurance com-

1 Project No. 349 of the Iowa Agricultural Experiment Station. The material in this bulletin is based upon the technical information set forth in Research Bulletin No. 185, "The Effect of Injury in Imitation of Hail Damage on the Development of the Corn Plant." Iowa Agr. Exp. Sta. June 1935. For a more technical and detailed discussion of the effects of hail on corn, the reader is referred to this bulletin.

2 This abridgement of certain phases of Research Bulletin No. 185 was prepared by Carl Hamilton of the Bulletin Office Staff.

bined, while, on the other hand, there is profound ignorance of plant response coupled with great uncertainty as to how seriously the plant is injured, or how successfully it can recover.

METHODS

Investigations to answer some of the problems arising along this line were started in 1928, at which time little experimental work had been done to determine the effect of mechanical injury on the yield of crops. The relative importance of leaf and stalk damage, the extent of recovery of crops damaged at different stages of growth, the stage of development of the crop when injury would result in the least recovery or the greatest reduction in yield, the effect of bruises on infection by smut organisms, were all questions arising in insurance adjustment of hail losses concerning which few data were available.

The 5-year investigation of this problem reported in this bulletin was started on a limited scale and gradually increased in scope until test fields were about 7 acres in area and involved many degrees and types of injury.

Two main types of injury are recognized in natural hail damage to corn. The first of these types is leaf injury, which may vary from that caused by a few scattered hailstones to severe injury where all leaves are torn in shreds and a large portion of the entire leaf area is removed from the plant. The other type is stalk and ear damage. Stalk injuries vary from small bruises, scarcely noticeable, to severe lesions caused by large hail driven by a high wind. In some cases the stalks may be entirely broken in two by the hailstones. Hail at silking time may bruise the silks, resulting in poor pollination. Later in the season the kernels may be crushed by hailstones, resulting in a bruised or moldy spot on the ear.

To obtain information on these two types of injury certain mechanical means were employed to imitate five different intensities of hail damage, namely: (1) Stripping, or total leaf removal; (2) shredding, in which all of the leaves were so damaged that they looked almost exactly as if they had been damaged by hail; (3) bruising of stalks and ears, in which the stalks and ears were bruised by striking each stalk five blows and each ear two blows, producing a bruise similar to that from a medium-sized hailstone striking the stalk with great force; (4) one-third and two-thirds defoliation, in which one-third and two-thirds of total leaf area were entirely removed; (5) minor leaf injury, consisting of a variety of minor injuries to the leaves of the plant. An

investigation was also carried over a 3-year period in an attempt to determine whether or not certain varieties were better able to withstand or overcome the effects of hail injury.

RESULTS

EFFECT OF LEAF INJURY ON THE YIELD AND QUALITY OF CORN

Discussion of results of these investigations is arranged by topics, and, with the exception of the results obtained during the severe drouth of 1930, all results are averages of the complete data obtained in the experiment. Also, in an attempt to minimize differences due to varying stages of maturity in different seasons, all data are presented by stage of maturity, rather than by date.

A very complete record was kept of yield and quality of corn from each type of injury. Each row of each replication was harvested and weighed separately. Notes were taken on the number of good ears, and number of nubbins and number of moldy ears. Stand counts were made each year so that the effect of stand on yield could be taken into consideration in the final results. A representative 25-pound sample from each type of injury at each date was saved and dried for use in moisture and shelling percentage determinations. Bushel weight was obtained on shelled samples. Final yields were computed in bushels of shelled corn per acre. All yields of injured rows were also computed as a percentage of the undamaged check rows.

Effect of Complete Defoliation (Stripping)

As would be expected from the fact that destruction of leaf area at certain stages was found to be the greatest determining factor in yield, complete defoliation, or stripping, was found to be one of the most serious types of injury which could be suffered by the corn plant. Table 1 and fig. 7 show the effect on yield of total defoliation at weekly intervals in 1928, 1929, 1931 and 1932. Figures 1 and 2 show the appearance of plants stripped at various stages of development. A study of these data indicates the importance of maximum leaf area to the corn plant.

In early June, when the corn had only five or six small leaves, cutting the plants off at the surface caused only a small reduction in yield since the remainder of the leaves unrolled normally and by tasseling time the injured rows

TABLE 1. YIELD OF CORN FROM PLANTS TOTALLY DEFOLIATED AT VARIOUS STAGES OF DEVELOPMENT.

Mean stage of maturity	Mean date	Yield in bushels per acre				Mean yield	
		1928	1929	1931	1932	Bu. per acre	Percentage of check
Check		49.0	85.1	52.0	67.6	63.4	
5 inches high, 4 leaves	6- 1		80.1	44.7		62.4	91.0
7 inches high, 5 leaves	6- 8	35.1	87.9	44.5	64.1	57.9	91.3
14 inches high, 7 leaves	6-15		78.4	44.5	39.7	52.5	77.0
2 feet high, 9 leaves	6-22	30.3	64.3	38.9	37.3	42.7	67.4
3 feet high, 11 leaves	6-29	31.2	50.9	15.3	35.0	33.1	52.2
4½ feet high, 13 leaves	7- 6		28.2	9.8	20.2	14.6	21.4
6 feet high, first tassels	7-13	8.6	17.2	3.9	1.3	7.8	12.3
8 feet high, 40 percent tasseled	7-20	0.1	0.3	0.5	0.0	0.2	0.3
85 percent tasseled, 60 percent silked	7-27	0.0	1.0	3.4	3.4	2.0	3.0
75 percent of silks dead	8- 3	9.3	12.3	10.8	14.6	11.7	18.5
Blister to early milk stage	8-10		19.9	19.4	26.5	21.9	32.1
Milk stage	8-17	23.9	39.0	27.7	39.8	32.6	51.4
Soft dough stage	8-24		55.0	37.0	48.2	46.7	68.5
Hard dough stage	8-31	38.0	68.7	44.6	58.0	52.3	82.5
Nearly mature	9- 7		86.6	45.0	62.3	64.5	94.6

appeared almost normal. Reduction in yield amounted to less than 10 percent. But as the season progressed and a greater and greater proportion of the total leaf area had developed and was consequently removed, the yield dropped sharply and in almost direct ratio to the percentage of leaf area removed. In mid July when the leaves were all unrolled and the leaf area was completely removed by defoliation the yield approached zero.

As table 1 shows, the period during which total leaf removal resulted in almost total loss of yield extended from the first tassel stage to the stage when the corn was 50 to 75 percent pollinated, a period of about 2 weeks, after which the yield began to rise sharply. As the season advanced and the ears continued to develop, leaf removal caused progressively less decrease in yield. This was not because the leaves ceased to be important but because more and more of the crop had been "made" before the leaves were removed.

Effect of Severe Shredding

A study of the data on shredding shows the same trends, with respect to effect on yield, as were obtained with complete defoliation. It being much more difficult to bring about the same intended degree of injury in this phase of the experiment, the more erratic results from year to year are probably due to the varying percentage of total leaf area which was destroyed. The average of the 4 years as shown in table 2 and fig. 7 approximate a fairly general trend, nevertheless.

During the first half of June, when only five or six of the lower leaves had unrolled, severe shredding reduced the yield about 1 percent for the first treatment, 2 to 3 percent for the second and 4 to 5 percent for the third. Yields began to drop rather rapidly from then on, being about 85 percent,

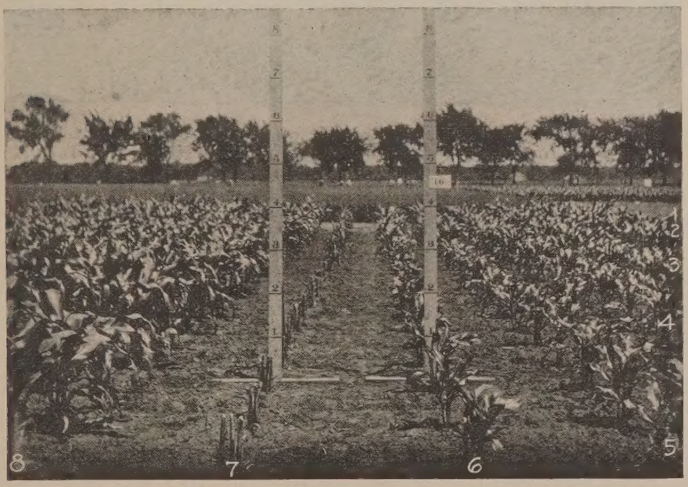

Fig. 1. Corn showing effects of total leaf removal at weekly intervals early in season. From right to left the date of the treatment and subsequent yield of the injured corn in percentage of normal or check rows: Row (1), border row; (2) check or normal row; (3) cut off at surface of ground on June 3 and yielded 91 percent of normal; (4) cut off at surface of ground on June 10 and yielded 91 percent of normal; (5) cut off at surface of ground on June 17 and yielded 77 percent of normal; (6) cut off to height of 4 inches on June 24 and yielded 67.4 percent of normal; (7) cut off to height of 1 foot on July 1 and yielded 52.2 percent of normal; (8) normal corn on July 1, cut off at 30 inches on July 8 and yielded 21.4 percent of normal. (Photo July 1)

(Dates in this and following legends are actual dates for the season during which the picture was taken; comparable dates in the tables are average dates for the period during which the experiment was conducted.)

Fig 2. Corn showing effect of complete defoliation in late July and early August. From right to left row (1) was stripped on July 21 and yielded 0.3 percent of a normal yield; (2) stripped on July 28 and yielded 3.0 percent of normal; (3) stripped on Aug. 4 and yielded 18.5 percent of normal; (4) stripped on Aug. 11 and yielded 32.1 percent of normal. These yields represent the part of the crop which had already been "made" at the time the leaves were removed. (Photo Aug. 25)

65 percent and 48 percent of check for the next three treatments, respectively, the last of which was given just as the tassels were ready to emerge. It will be noted that yields began to drop rapidly at exactly the period when the leaves began to unroll more rapidly. This critical period continued for 2 weeks during the tasseling and silking stage of the plant's development.

If an average of 50 percent of the leaf area was removed by shredding, which is a reasonable assumption in the light of data on percentage of leaf removed by this process, it appears that the percentage of leaf removed at the most critical stage would reduce the yield proportionately. This result checks rather closely with the data on stripping. About June 29, when approximately 50 percent of the potential leaf area of the plant was removed in the stripped plots, the yield was about 50 percent of normal.

Also as in the case of complete defoliation, yields began to increase on the shredded plots following the critical tasseling and silking stage.

Effect of Removing One-Third and Two-Thirds of the Leaves

Table 3 shows that the trend in yields of corn suffering one-third and two-thirds leaf removal is very similar to the results of the stripping and shredding experiments. There was a very slight decrease in yield both for the one-third and two-thirds defoliation in the first 3 weeks. Following this there was a sharp drop to a 30 percent yield for the two-thirds and a 70 percent yield for the one-third defoliated at tasseling time. After the low point at the tasseling-silking period, a sharp rise for the next 2 weeks is noted for both the one-third and two-thirds defoliated, and then a more gradual rise back to 92 and 90 percent yield, respectively, at the nearly mature stage. Again the results show close relation between percentage of leaf area removed and the percentage decrease in yield at the critical stage of development.

TABLE 2. YIELD OF CORN FROM PLANTS THE LEAVES OF WHICH WERE SHREDDED AT VARIOUS STAGES OF DEVELOPMENT.

Mean stage of maturity	Mean date	Yield in bushel per acre				Mean yield for 1929-1931-1932	
		1928	1929	1931	1932	Bu. per acre	Percent of check
Check		49.0	78.3	63.0	54.6	65.3	
5 inches high, 4 leaves	6- 1		83.6	61.8		72.7	102.8
7 inches high, 5 leaves	6- 8	45.1	75.5	60.3	52.1	62.6	95.9
14 inches high, 7 leaves	6-15		84.9	61.3	55.3	67.2	102.9
2 feet high, 9 leaves	6-22	46.2	70.9	52.5	51.0	58.1	89.0
3 feet high, 11 leaves	6-29	43.7	71.3	35.8	39.6	48.9	74.9
4½ feet high, 13 leaves	7- 6		44.8	19.5	23.8	29.4	45.0
6 feet high, first tassels	7-13	38.3	31.4	16.1	24.2	23.9	36.6
8 feet high, 40 percent tasseled	7-20	39.0	45.3	27.1	25.1	32.5	49.8
85 percent tasseled, 60 percent silked	7-27	37.2	62.0	39.9	27.0	43.0	65.8
75 percent of silks dead	8- 3	39.3	54.5	42.4	32.0	43.0	65.8
Blister to early milk stage	8-10		66.7	42.3	31.7	46.9	71.8
Milk stage	8-17	44.9	66.1	50.5	35.3	50.6	77.5
Soft dough stage	8-24		70.1	50.6	42.6	54.4	83.3
Hard dough stage	8-31	47.7	71.3	56.0	48.1	58.5	89.6
Nearly mature	9- 7		76.7	60.4	50.2	62.4	95.6

TABLE 3. YIELD OF CORN FROM PLANTS PARTIALLY DEFOLIATED AT DIFFERENT STAGES OF DEVELOPMENT

Mean stage of maturity	Mean date	One-third of leaves removed				Two-thirds of leaves removed			
		Yield in bu. per A.		Mean yield		Yield in bu. per A.		Mean yield	
		1931	1932	Bu. per A.	Percent check	1931	1932	Bu. per A.	Percent check
Check		52.2	60.4	56.3		52.3	48.8	50.6	
5 inches high, 4 leaves	6- 1	54.3			104.0*	51.7		51.7	98.9*
7 inches high, 5 leaves	6- 8	50.2	62.4	56.3	100.0	48.8	50.6	49.7	98.2
14 inches high, 7 leaves	6-15	51.6	60.3	56.0	99.5	51.0	50.3	50.7	100.2
2 feet high, 9 leaves	6-22	52.2	59.3	55.8	99.1	48.8	46.9	47.9	94.7
3 feet high, 11 leaves	6-29	38.3	55.6	47.0	83.5	34.2	35.2	34.7	68.6
4½ feet high, 13 leaves	7- 6	42.3	52.6	47.5	84.4	31.4	27.9	29.7	58.7
6 feet high, first tassels	7-13	40.8	43.6	42.2	75.0	24.4	17.1	20.8	41.1
8 feet high, 40 percent tasseled	7-20	34.8	44.1	39.5	70.2	16.8	10.6	13.7	27.1
85 percent tasseled, 60 percent silked	7-27	39.5	50.2	44.9	79.8	27.0	22.6	24.8	49.0
75 percent of silks dead	8- 3	47.0	51.8	49.4	87.7	32.5	28.4	30.5	60.3
Blister to early milk stage	8-10	47.9	48.6	48.3	85.8	33.3	31.7	32.5	64.2
Milk stage	8-17	43.2	56.6	49.9	88.6	38.7	34.1	36.4	71.9
Soft dough stage	8-24	40.7	52.5	46.6	82.8	42.6	36.2	39.4	77.9
Hard dough stage	8-31	46.3	60.1	53.2	94.5	46.4	43.5	45.0	88.9
Nearly mature	9- 7	44.5	58.7	51.6	91.7	47.7	41.6	44.7	88.3

*1931 only.

Minor Leaf Injuries

The purpose of this phase of the investigation was to determine the effect of five types of leaf injury relatively less severe than those previously described, determining whether the result of hailstones tearing holes in leaves, or breaking the midribs of the leaves, would seriously affect the yield. These studies were carried on over a 3-year period with the five different types of injury being inflicted at what were considered the 3 most critical stages in the development of the plant, namely: (1) Pre-tassel stage, about a week before the tassels appeared; (2) full tassel stage, when the corn was practically all tasseled and about 50 percent silked; (3) early milk stage, when most of the ears

were "in the milk" and before any had developed to the soft dough stage. The five types of injury considered in this phase of the experiment were thought to simulate rather closely types of minor injury often suffered by hailed fields. (table 4). The injuries consisted of the "half leaf" injury in which half the leaf was removed; "half shredded" injury in which the tip half of each leaf was shredded into ribbons about ¼ inch wide, less than 5 percent of the total area being removed; "cut opposite" injury in which each leaf was cut from the outer edges to the midrib, the cuts on each side being opposite; "cut alternate" injury in which the

TABLE 4. YIELDS IN PERCENTAGE OF CHECK FROM CORN PLANTS SUBJECTED TO FIVE TYPES OF LEAF INJURY AT VARIOUS STAGES OF DEVELOPMENT.
1931-1932

Stage of maturity	Outer half of each leaf cut off	Outer half of each leaf shredded	Leaves cut to midrib on each side. Cut opposite	Leaves cut to midrib on each side. Not opposite	Midrib only cut
1931					
July 8—56 inches high, 13 leaves	70.2	94.2	95.5	96.6	88.7
July 21—99 percent tasseled, 17 percent silked	53.2	83.0	88.6	96.8	80.5
Aug. 11—Early milk stage	92.9	95.1	99.2	93.9	93.6
1932					
July 5—56 inches high, 12 leaves	76.5	98.3	94.6	99.8	83.1
July 26—98 percent tasseled, 85 percent silked	81.2	95.6	90.7	94.8	80.1
Aug. 9—Early milk stage	80.3	90.9	96.9	98.1	90.1
Mean of 1931 and 1932					
July 6	73.4	96.3	90.2	98.2	85.9
July 24	67.2	89.3	89.7	95.8	80.3
Aug. 10	86.6	93.0	98.1	96.0	91.9

Mean yield of check 1931—46.9 bu. 1932—64.5 bu.

Fig. 3. Corn showing effect of shredding early in season. From left to right, row (1) shredded on June 17 and yielded 102.9 percent of normal; (2) shredded on June 24 and yielded 89 percent of normal; (3) normal plants which were shredded on July 1 and yielded 74.9 percent of normal. It should be taken into account that a certain amount of the leaf area was destroyed in the shredding process, consequently these results check very closely with the defoliation results in which it is shown that yields are decreased in about the same proportion as the percentage of leaf area removed. (Photo June 24)

leaves were cut from edge to midrib, the cuts being between 8 and 10 inches apart instead of opposite; and the "cut midrib" injury in which the midrib was cut without otherwise injuring the leaf. The results of the "cut alternate", "cut opposite" and "half shredded" injuries showed a maximum decrease in yield of 4.2, 10.3 and 10.7 percent, respectively. The "cut midrib" injury was found to be barely significant as far as results were concrned, while the "half leaf" injury was found to be highly significant from the standpoint of yield.

Substantiating earlier observations that total leaf area is of prime importance in determining yield, it is obvious from these data that the two most serious of these five so-called minor injuries were those in which the largest percentage of leaf area was removed.

EFFECT OF BRUISING STALKS AND EARS AND OF SHREDDING THE LEAVES

This phase of the investigation involved two distinct types of injury, (a) shredding of the leaves and (b) bruising of the stalks and ears. Both occur in natural hail damage in varying degrees of severity depending upon the type of the storm.

Effect of Bruising Only

Results of this experiment for the years 1928 and 1929 are separated from those of 1931 and 1932 because they are not directly comparable. In 1928 a reduction in yield of approximately 25 percent resulted from shredding during the tasseling-silking period (table 2). During the same period, shredding the leaves and bruising the stalks caused a reduction in yield of about 42 percent. In 1929 the two types of injury, during the critical period, brought about a maximum reduction of 60 percent. During the same period bruising alone brought about a reduction of between 25 and 30 percent. This indicates that during 1929 bruising alone was about half as serious as shredding. The 2 years' results indicate that bruising alone was more serious than bruising

Fig. 4. Corn showing the effects of shredding in July. From left to right, row (1), which is row (3) of fig. 3, shredded on July 1, yielded 74.9 percent of normal; (2) shredded on July 7 and yielded 45 percent of normal; (3) which was shredded a week later on July 15, yielded 36.6 percent of normal. (Photo July 9)

TABLE 5. PERCENTAGES OF BROKEN STALKS AND DAMAGED KERNELS TOGETHER WITH YIELD OF GRAIN FROM CORN PLANTS SUBJECTED TO TWO TYPES OF INJURY AT VARIOUS STAGES OF DEVELOPMENT.
1931-1932

Mean stage of maturity	Mean date	1931		1932		Percent of damaged kernels	Mean yield	
		Percent of broken stalks	Yield per A. in bu.	Percent of broken stalks	Yield per A. in bu.		In bu. per A.	In percent of check
Stalks and ears bruised								
Check		2.3	57.7	1.5	54.7	0.63	56.2	
56 inches high, 12 leaves	7- 6	4.9	49.3	14.1	44.3	0.15	46.8	83.3
6½ feet high, 10 percent tasseled	7-13	8.8	39.6	21.7	38.4	2.20	39.0	69.4
8 feet high, 70 percent tasseled	7-20	5.8	37.9	41.1	34.8	0.81	36.4	64.8
70 percent silked	7-27	22.1	39.5	47.5	34.0	2.23	36.8	65.5
70 percent of silks dead	8- 3	31.1	42.9	51.1	39.9	2.27	41.4	73.7
Early milk stage	8-10	40.1	46.4	56.1	35.5	2.75	41.0	73.0
Late milk stage	8-16	59.4	45.8	64.5	48.4	2.42	47.1	83.8
Soft dough stage	8-23	71.1	47.9	35.4	46.8	1.18	47.4	84.3
Hard dough stage	8-30	86.5	50.3	32.1	51.1	3.04	50.7	90.2
Nearly mature	9- 6	70.4	53.9	39.5	52.1	2.18	53.0	94.3
Stalks and ears bruised and leaves shredded								
Check		3.0	55.2	2.0	54.9	0.51	55.1	
56 inches high, 12 leaves	7- 6	4.9	18.7	10.3	20.2	0.75	19.5	35.4
6½ feet high, 10 percent tasseled	7-13	8.5	11.4	16.0	14.0	2.03	12.7	23.0
8 feet high, 70 percent tasseled	7-20	8.5	19.4	18.7	21.1	1.74	20.3	36.8
70 percent silked	7-27	16.0	25.8	29.5	24.4	3.43	25.1	45.6
70 percent of silks dead	8- 3	21.9	32.6	25.5	28.1	3.06	30.4	55.2
Early milk stage	8-10	29.8	34.1	39.7	30.9	1.88	32.5	59.0
Late milk stage	8-16	48.1	41.2	43.4	37.6	1.05	39.4	71.5
Soft dough stage	8-23	63.8	45.7	26.4	47.0	2.11	46.4	84.2
Hard dough stage	8-30	76.9	51.1	41.7	47.8	2.52	49.5	89.8
Nearly mature	9- 6	74.5	51.5	45.0	48.5	0.88	50.0	90.7

when in combination with shredding. In 1931 and 1932 bruising the stalks and ears, but with no shredding, caused a 20 percent reduction in yield at the beginning of the period, increasing to 35 percent reduction at the critical period, as compared with a 50 percent reduction for severe shredding at the same period (table 5). The trend is very similar to that of the different types and degrees of leaf injury except that the critical stage seems to come later in the season, probably due to the fact that the ears had not formed when the bruising was begun and consequently there was no ear injury.

Comparison of Shredding and Bruising

A study of the results for 1931 and 1932 shows that while bruising caused 36 percent reduction in yield at the critical period and shredding caused a 65 percent reduction, the two

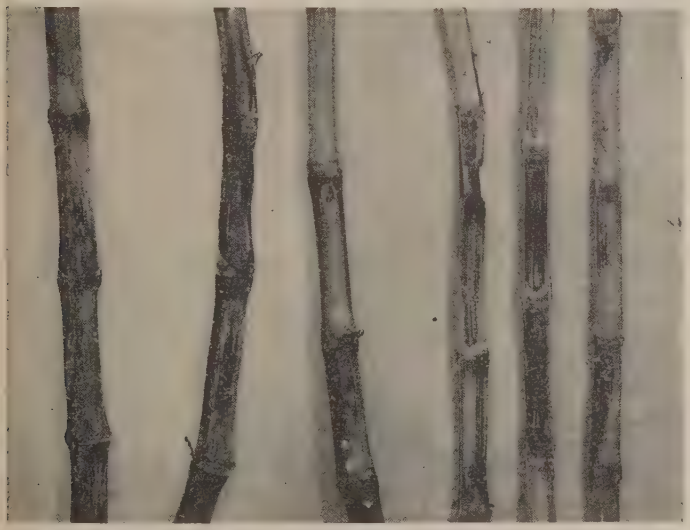

Fig. 5. Stalks bruised in July. The three at the right are split to show how far the injury extended. The three at the left show the outward appearance of typical bruises. (Photo Oct. 18) An examination of the data on broken stalks presented in table 9 shows that the percentage of broken stalks increased as the season advanced and the ears became heavier. Since there was no positive correlation between broken stalks and reduction in yield, the injury due to bruising was probably so severe that the breaking over of the stalk caused no additional damage.

combined caused less than 10 percent additional injury over shredding alone. An explanation of this result probably should be based on the fact that the two types of injury together do not upset the normal balance of the plant proportionately as much as either of them alone. For this reason both types of injury on the same plant do not reduce yields by the same proportion that they do when each is on a different plant.

Damage to Ear and Kernel

The effect of ear bruises inflicted at different stages of development may be seen in fig. 6. As far as reduction in yield was concerned, this type of injury did not seem to be particularly harmful, never causing more than 10 percent additional reduction.

Market Grade of Bruised Corn

In this phase of the investigation the damaged kernels from the bruised and the bruised and shredded plots were compared with check plots. In most instances it was found that the grade of the injured corn had been reduced somewhat. Whereas the check plots all graded No. 1, the injured plots in most instances graded No. 2. This was not thought to be significant, however, in view of the fact that very little corn marketed from the farm will grade higher than No. 2 because of moisture content.

Fig. 6. Ears bruised at succeeding weekly intervals from silking stage (No. 1), to mature stage (No. 10). Note the absence of mold from Nos. 1, 2, 3, 9 and 10 and the extent of the moldy spots on the others. (Photo Oct. 18) the number of moldy kernels due to the bruising of the ears (as shown in table 5) was increased about 2 percent. This would cause corn from the bruised ears to grade No. 2 due to the damaged kernels.

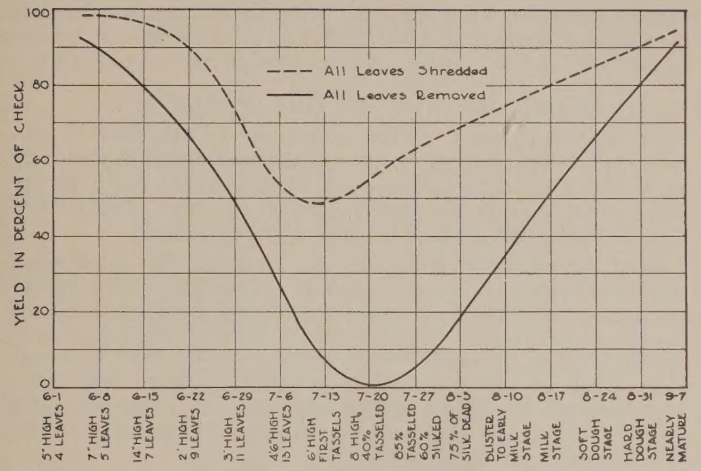

Fig. 7. The two lines on this graph show the average yield, in percentage of normal or uninjured plants, from the plants which were totally defoliated at various stages and from plants whose leaves were shredded at various stages of maturity.

The broken line shows that shredding of leaves caused the most serious damage at the stage when the first tassels were beginning to appear—reducing the yield to slightly less than 50 percent of normal. The solid line shows that complete leaf removal was most serious when the corn was approximately 40 percent tasseled—reducing the yield to practically nothing at that particular stage. It is important to note the stage of maturity, rather than the date, at which the various injuries proved most severe.

EFFECT ON WEIGHT PER BUSHEL

The greatest reduction in weight per bushel occurred when the leaves were removed or severely shredded during the period when the corn was between 60 percent silked and in the milk stage. A reduction of about 15 percent in weight per bushel occurred during this time on the stripped plants. Previous to this time (June 20 to July 13) complete removal of unrolled leaves reduced the weight per bushel only 3 to 5 percent. Following the milk stage and up to the hard dough stage the weight was reduced about 3.5 percent.

VARIETAL RESPONSE TO LEAF INJURY

The data on variety comparisons seem to justify the conclusions that there probably is no significant difference between varieties in their response to leaf injury. Six varieties were used in this phase of the experiment, covering as wide a range in corn types and breeds as possible. While the

ranker growing, later varieties seem to be hurt a little less by the leaf shredding, the difference may be due to failure to inflict the injury at exactly the same stage of maturity.

EFFECT OF INJURY ON TIME OF MATURITY

In the adjustment of hail losses one of the factors frequently in controversy is the question of delayed maturity as a result of early storms. A severe storm early in the season may almost completely destroy the corn plant, yet in 2 or 3 weeks the plant may appear quite normal.

Leaf shredding delayed maturity from 0.5 day to 2.3 days, depending upon the time of injury. Stripping, which meant complete destruction of the above ground parts of the plant up until about June 15, (see fig. 1) delayed maturity from 1.8 to 5.5 days depending upon the time of injury. It seems reasonable to assume that in a normal season with corn maturing rather rapidly, a 2 to 5-day delay in maturity might result in a 2-to 5-bushel decrease in yield if frost came before the injured corn was mature.

SMUT INFECTION IN INJURED PLANTS

Another point of controversy in the settling of insurance losses is the difference of opinion concerning losses which may or may not result from smut infection following hail injury. The data collected on this phase of the experiment show that there was an increase in smut on the plants injured between June 29 and July 13, or for the 2 weeks just preceding the appearance of the tassels. Before and after that period there were about the same number of smut masses on the injured plants as on the checks.

The data in table 6, which show the average of all types of injury on smut infection, indicate that there were no significant differences in smut infection because of leaf injury as compared with stalk bruises. The fact that smut infection on shredded and stripped plants runs slightly higher than that on bruised plants is accounted for by the fact that the latter type of injury was not started until the critical point in the growth of the plant was nearly past.

EFFECT OF DRY WEATHER ON THE YIELD OF INJURED CORN

The results of the 1930 investigations have not been included with the other years because they were so unusual as a result of the severe drouth of that season. Some idea of the severity of the dry weather may be gained from the fact that the check or normal plots during 1930 averaged only 2.4 bushels per acre. A great many of the results

TABLE 6. NUMBER OF SMUT MASSES PER 100 PLANTS BY SEASON AND BY STAGE OF MATURITY.

(All types of injury averaged)

Average stage of maturity when injured	1928	1929	1931	1932	Mean of all years	Mean of '29 '31 and '32
Mean of all checks	5.4	18.5	11.2	4.5	9.9	11.4
June 1—5″ high, 4 leaves		21.2	16.7			
June 8—7″ high, 5 leaves	7.0	22.0	12.3	6.9	12.1	13.7
June 15—14″ high, 7 leaves		26.4	10.3	4.5		13.7
June 22—2′ high, 9 leaves	2.3	15.3	9.5	4.2	7.8	9.7
June 29—3′ high, 11 leaves	10.7	33.2	23.5	9.8	19.3	22.2
July 6—4½′ high, 13 leaves	17.0	38.2	24.7	11.0	22.7	24.6
July 13—6′ high, first tassels	10.9	41.4	17.4	9.2	19.8	22.7
July 20—8′ high, 40% tasseled		12.4	15.1	6.4		11.3
July 27—85% tasseled, 60% silked	6.9	20.7	9.7	4.5	10.5	11.6
Aug. 3—75% of silks dead		23.2	7.9	5.2		12.4
Aug. 10—Blister to early milk stage	7.0	14.9	8.7	4.1	8.7	9.2
Aug. 17—Milk stage	6.5	11.7	13.5	4.0	8.9	9.7
Aug. 24—Soft dough stage		20.0	6.9	3.7		10.2
Aug. 31—Hard dough stage	4.3	14.5	8.3	4.7	8.0	9.2
Sept. 7—Nearly mature		16.1	7.9	3.2		9.1

which were obtained that year were erratic due to factors other than the imitated hail injury. Some of the results are also contrary to the generally accepted ideas of hail insurance adjusters and farmers who assume that hail injury in a dry season or when followed by a severe dry spell will be much more serious than in a normal season. The most significant fact to be observed from the 1930 results was that the types of injury which involved considerable loss of leaves showed less reduction in yield than in years of normal rainfall. The fact that defoliation at certain periods actually brought about an increased yield over the check plots may be explained in two ways. Partial defoliation early in the season, if done before transpiration had depleted the soil moisture, would result in a greater supply of moisture for the plant's later use. The other explanation might be based on the fact that if dry weather limited a normal 60-bushel yield to 20 bushels the normal leaf area would not be needed. Perhaps 50 percent of the area or less could manufacture enough carbohydrates to produce the 20 bushels. Under such conditions removal of part of the leaves would not reduce the yield as much, in comparison with the check plots, as this same removal would in a normal season.

Until the early part of July in 1930 the rainfall was adequate, April, May and June each having a record of over 3 inches. The rainfall for the remainder of the season was as follows: July 4, 0.4 of an inch; July 21, 0.1; August, 0.91 of an inch coming in six scattered showers which barely moistened the surface; Sept. 14, 0.06 of an inch and Sept. 25 and 26, 2 inches, after the corn was mature. The above data show that there was no rain of any value to a growing crop after July 4. The plentiful moisture supply previously had started the corn off with a large top growth and a relatively deficient root growth so that it was particularly vulnerable to drouth during the time the ears were forming.

The yield of the check rows in 1930 was only 2.4 bushels per acre, the plots having all unrolled leaves removed on June 23 yielded 13 bushels and on June 30, 11.9 bushels per acre. This was at a period when about 50 percent of the leaves were unrolled, and it was also just at the end of a period of plentiful rainfall and the beginning of a severe drouth. The check rows, which developed all their leaves, soon exhausted the soil moisture so that practically no crop was produced. On the other hand the rows with half their normal leaf area were saving soil moisture, because of reduced transpiration, and were enabled to produce part of a crop. They probably had sufficient leaf area to develop as much of a crop as the dry conditions permitted.

Results of removing two-thirds of the leaves were very similar to total leaf removal except that they were not so pronounced. Yields of the injured plots remained consistently higher than the check rows up until the June 30 treatments. Removal of two-thirds of the leaves obviously would not reduce transpiration as much as total leaf removal. During the critical tasseling-silking period yields were reduced to between 40 and 50 percent, while in 1931 and 1932 they were reduced to 30 percent of a normal crop for the same period.

Removing one-third of the leaves in 1930 resulted in a much greater proportionate reduction in yield than two-thirds defoliation, and this treatment at the critical period was somewhat more injurious than the same treatment in 1931 and 1932. Bruising the stalks was somewhat less harmful in 1930. But bruising and shredding, with a 50 percent reduction in leaf area (and transpiring area), reduced yields less in 1930 than in 1931 and 1932, another indication that the saving of soil moisture was more important than having a maximum photosynthetic area.